Species frequency of communities along northern slope of Changbai Mountain, Northeast China

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Abstract: The species distribution frequency of communities from 700 m to 1900 m along northern slope of Changbai Mountain was studied by using Raunkiaer's frequency analysis methods in summer of 1999. The variation on composition and structure of communities with the increase of elevation was displayed from the point of view of frequency. The results showed that for all the species of community including tree, shrub and herb, the frequency presented a "L" shape even though there were difference among communities. The percentage of high frequency species increased with the increase of elevation. As one of important index in reflecting species spatial patterns, frequency not only show up the importance of species, but also the evenness of spatial distribution in community. Frequency figure could reveal the complexity and diversity of community at some extent.
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Introduction

As an important index reflecting species spatial patterns, frequency reflects not only the importance of species, but also the evenness of spatial distribution in community (Lin 1986; Magurran 1988; Dale 1999). Frequency figure could reveal the complexity and diversity of community at some extent. Raunkiaer (1918) divided frequency indices into five classes, namely, A: 1%-20%, B: 21%-40%, C: 41%-60%, D: 61%-80%, and E: 81%-100%, and based on 8 078 frequency indices of herbaceous vegetation in North Europe, and concluded a law of frequency as follows: A>B>C≥ or ≤D<E. According to the distribution of frequency indices, a "L" shape standard frequency figure could be drawn (Wang 1996). In this study, based on frequency analysis of 13 forest communities along 700 m to 1 900 m in northern slope of Changbai Mountain, the variation law of forest communities along gradient was explored, in point of distribution frequency of species.

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Study area and methods

Study area

The study was conducted along the altitudes of 700 m to 1900 m on the northern slope in Changbai Mountain, with a horizontal distance of 40 km. The annual temperature in area with altitude of 700 m averages 2.8°C and it belongs to the typical temperate zone. At the altitude of 1 900 m, the average annual temperature is –3.3 °C and it belongs the sub-alpine climate (Chi *et al.* 1981; Yang 1981). The precipitation increases with altitude rising. At the altitudes of 700 m and 1 900 m, the precipitation is 680 mm and 1 038 mm respectively (Chi *et al.* 1981; Yang 1981; Zhang *et al.* 1984). Along with the variety of altitude, there exist different vegetation types: broad-leaved Korean pine forest (altitude lower than 1 100 m), dark coniferous forest (from 1 100 to 1800 m), and sub-alpine *Betula ermanii* forest (1 800-2 000 m) (Wang *et al.* 1980; Zhao 1980; Li *et al.* 1994).

Sampling

The sampling was set by gradient pattern. From altitudes of 700 m to 1 900 m, thirteen 32-m × 32-m plots were investigated with an interval of 100 m in altitude, and each plot was composed of sixteen 8-m × 8-m small plots.

Investigation

Basic status such as altitude, slope degree, and coverage of the plots was investigated, and a sketch of each plot was drawn. In each small plot, for herbs and shrubs, species, abundance, coverage, average

and height were investigated, and for trees, species, diameter and height were investigated. The field research was carried out in the summer of 1999.

Frequency analysis

In this study, frequency analysis was based on the data of sixteen 8-m × 8-m small plots. Based on calculating the frequency index of each species at different altitudes, the distribution frequency was classified according to Raunkiaer's frequency analysis method.

Results

The frequency distribution of all the species in every sample plot with varied altitudes was shown in Fig. 1. The frequency figures were approximately in a typical "L" shape in broad-leaved/Korean pine forest at and under 1000 m, which means that the ratio of low frequency species (class A) was high, with less difference in classes at altitudes of 800 m and 900. For the forest communities that distributes at and above elevation of 1100 m, besides the class A (frequency lower than 20%) had high percentage, the percentage of class E (frequency higher than 80%) was also high. In dark coniferous forest the frequency of about 1/3 species reached 80% or over, which means 30% species spread all over the forest. Frequency distribution of *Betula ermanii* forest at altitudes of 1 800 m and 1 900 m generally followed Raunkiaer's law, but class E also had a high ratio.

According to species frequency (Table 1) of different layers of community, at altitudes of 700 m and 1 000 m, the arbor species with low frequency took absolute dominance. The percentages of the tree species with frequency lower than 20% at the two altitudes were 68 and 59 respectively, and 90 percent of the species had frequency bellow 40% and no species had frequency over 80%. In the communities at altitudes of 800 m and 900 m, there was no evident variation among species number of different frequency classes, accounting for 20% for each class. It was clear that just fewer or no arbor species grow in broad-leaved/Korean pine forest under 1 000 m, which means no absolutely dominant tree can spread all over the forest. Most species had low frequency, and different frequency species averagely shared resources, which resulted in the character of multi-dominant species in the community.

In dark coniferous forest at altitudes of 1 100-1 700 m, frequency figure of trees approximately presented "L" shape, while the two sidelines of "L" were almost equal, sometimes even showed in reverse "L". Species with frequency over 80% took up a high percentage, with an average of 38. These species mostly were dominant species of the community. This indicates that species composing the community was relatively humdrum. The ratio of widespread species with high frequency (class E) and rare species with low frequency (class A) were 38% and 28% respectively. These two kind of frequency species and a few kinds of companion tree species composed main body of the community.

In the community of *Betula ermanii* forest at 1 800 m, frequencies of the other trees were lower than 20%, except that frequency of *Betula ermanii* was 100%. However, also in *Betula ermanii* forest, but at 1 900 m, frequency of *Larix olgensis* exceeded 80%.

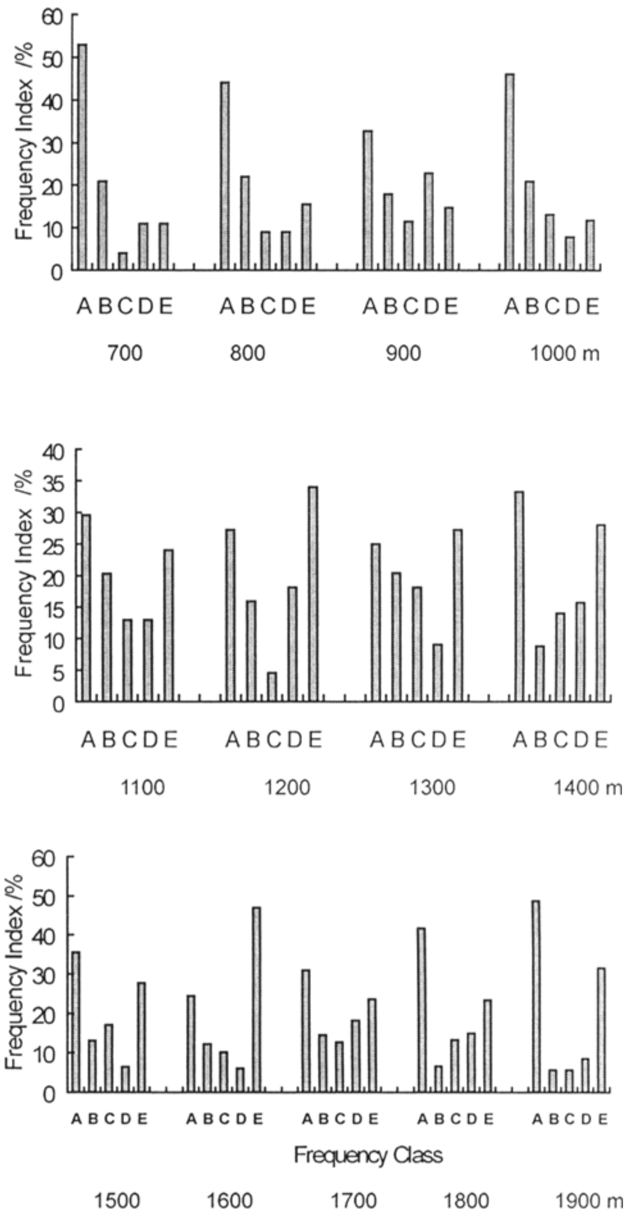

Fig.1. Graphical analysis of species frequency in forest communities at different elevations in northern slope of Changbai Mountain

A: 1%-20%, B: 21%-40%, C: 41%-60%, D: 61%-80%, E: 81%-100%

The frequency figures of shrubs were similar with those of trees. In the broad-leaved Korean pine forest at altitudes of 700 m and 800 m, species with frequency lower than 40% owned 85% and 87% respectively. The result showed that with fewer mutual species, there was a remarkable variation in constitute of shrubs between different sampling areas, and the spatial distribution of the species was uneven and they held a high heterogeneity. At elevations of 900 m and 1000 m, species with middling frequency were abundant, which resulted in the homogeneity between sampling areas. However, because of low percentage of high frequency species, there were fewer mutual species, these communities also showed the character of uneven species distribution and high spatial heterogeneity.

Table 1. Species frequency of different layers of forest communities at different elevations

Elevation /m	Layer	Frequency Class A N	A %	B N	B %	C N	C %	D N	D %	E N	E %
700	Trees	13	68.42	4	21.05	1	5.26	1	5.26	0	0
	Shrubs	13	65	2	10	1	5	2	10	2	10
	Herbs	27	44.26	15	24.59	2	3.28	8	13.11	9	14.75
800	Trees	4	20	4	20	4	20	3	15	5	25
	Shrubs	9	60	4	26.67	0	0	0	0	2	13.33
	Herbs	21	50	9	21.43	3	7.14	4	9.52	5	11.9
900	Trees	4	28.57	2	14.29	3	21.43	3	21.43	2	14.29
	Shrubs	2	13.33	3	20	2	13.33	6	40	2	13.33
	Herbs	14	43.75	6	18.75	2	6.25	5	15.63	5	15.63
1000	Trees	10	58.82	4	23.53	2	11.76	1	5.88	0	0
	Shrubs	3	21.43	3	21.43	4	28.57	2	14.29	2	14.29
	Herbs	22	48.89	9	20	4	8.89	3	6.67	7	15.56
1100	Trees	4	30.77	3	23.08	1	7.69	0	0	5	38.46
	Shrubs	2	22.22	3	33.33	2	22.22	1	11.11	1	11.11
	Herbs	10	31.25	5	15.63	4	12.5	6	18.75	7	21.88
1200	Trees	4	28.57	1	7.14	2	14.29	2	14.29	5	35.71
	Shrubs	1	12.5	3	37.5	0	0	2	25	2	25
	Herbs	7	31.82	3	13.64	0	0	4	18.18	8	36.36
1300	Trees	1	8.33	3	25	2	16.67	1	8.33	5	41.67
	Shrubs	4	57.14	1	14.29	2	28.57	0	0	0	0
	Herbs	6	24	5	20	4	16	3	12	7	28
1400	Trees	3	30	0	0	2	20	1	10	4	40
	Shrubs	2	25	1	12.5	2	25	2	25	1	12.5
	Herbs	14	35.9	4	10.26	4	10.26	6	15.38	11	28.21
1500	Trees	4	44.44	0	0	2	22.22	0	0	3	33.33
	Shrubs	2	25	3	37.5	0	0	1	12.5	2	25
	Herbs	21	35.59	7	11.86	11	18.64	4	6.78	16	27.12
1600	Trees	1	16.67	1	16.67	0	0	1	16.67	3	50
	Shrubs	3	75	0	0	0	0	0	0	1	25
	Herbs	8	20.51	5	12.82	5	12.82	2	5.13	19	48.72
1700	Trees	3	42.86	0	0	0	0	2	28.57	2	28.57
	Shrubs	5	62.5	2	25	0	0	0	0	1	12.5
	Herbs	9	22.5	6	15	7	17.5	8	20	10	25
1800	Trees	4	80	0	0	0	0	0	0	1	20
	Shrubs	3	42.86	0	0	1	14.29	1	14.29	2	28.57
	Herbs	18	37.5	4	8.33	7	14.58	8	16.67	11	22.92
1900	Trees	3	60	0	0	0	0	0	0	2	40
	Shrubs	2	25	0	0	0	0	2	25	4	50
	Herbs	12	54.55	2	9.09	2	9.09	1	4.55	5	22.73

Although the frequency figures of shrubs of dark coniferous forest were approximately "L" shape in common, there was significant variation between different altitudes. The highest spatial heterogeneity appeared at altitude of 1300 m. At altitudes of 1600 m and 1700 m, the frequency figures were almost really "L" shape, and the species with middling frequency were fewer or absent, the shrubs were mainly composed of few kind of widespread and many rare species. The number of shrub species in dark coniferous

forest was small, the average of whole altitudes was 7, with 1-2 kind of widespread species, and variation between other frequency species was also not evident.

Because of high percentage of herbage vegetation in all communities, and they were the base for whole vegetation frequency figures, frequency figures of herbs at every elevation were coincident with those of all plants. Figures of broad-leaved Korean pine forest under altitude of 1100 m are basically "L" shape, and species with low frequency (class A) owned high ratio (the average percent is 46%), 68% of species were those of whose frequency were under 40%, class E owned 14%. In dark coniferous forest higher than 1100 m, class A and E were dominant, sometimes class E even higher than A, which means the frequency of main species were lower than 20% or higher than 20%. Averagely, 30% of herbage vegetation held frequency higher than 80%, so, they were almost spread all over the forest. Frequency of *Betula ermanii* forest followed Raunkiaer law in general, but percentage of class E was high.

Conclusion and discussion

As an important index of spatial pattern of species, frequency can reflect not only the importance of population in community, but also the uniformity in horizontal pattern. However, this uniformity has another ecological means in community ecology. In common, evenness is measured by abundance of species and their proportion, namely, the ratio of quantity of each species (individual, biomass and canopy etc.) to whole species in the community, which can indicate the quantitative importance and uniformity of species. It is a concept that shows the general state of whole species in the community. However, frequency mainly reflects horizontal uniformity, and is a concept that only used to study the state of one species in community.

Raunkiaer law ("L" shape) showed that rare species were predominant in community, widespread species owned high percent as well, and percentage of middling frequency was relative low. Commonly, widespread species with high frequency were usually dominant species in relevant community, these species spread all over the community, building the frame of the community. Together with dominant species, associated species which possessed of middling frequency composed the main body of community. Rare species with low frequency showed the complexity of community and diversity of the components.

The higher frequency of rare species was, the more variant composition of different sampling areas showed, and the smaller mutual species had, which indicates unevenness and high heterogeneity of spatial pattern in community. The higher percentage of high frequency species was, the more mutual species between sampling areas held, and the species number was limited, so community showed a high homogeneity. As community structure was humdrum, each species owned a high frequency, species with high frequency were dominant. So, Frequency figure could reveal the complexity and diversity of community at some extent.

Frequency figures of different elevations and layers along Changbai Mountain basically showed "L" shape, while variation along altitudes was evident. As altitude increasing, percentage of high frequency species (class E) raised in all layers, this trend was even distinct in figures of trees and shrubs. At the forest limit, species diversity was very low, *Betula ermanii* dominate the whole community, there were just a few species in each sampling area. It's obvious that complexity and diversity of community could be learned more clearly by using frequency analysis.

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